GUEST EDITORIAL

Special Section on Color Imaging: Device-Independent Color, Color Hardcopy, and Graphic Arts

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It is time to reconsider our research priorities. The veterans in our community started out in an age when the image processing tools in the publishing industry were graphic arts cameras and screens, pin registers, knives, and goldenrod paper. Their contribution was to invent the technologies that brought us from mechanical processes to electronic publishing: scanners, image enhancement, colorimetric color control, color management, perceptually lossless image compression, and digital halftoning among others.

It is a sign of the exponential progress in science and technology, that the same generation of scientists and engineers is able to contribute to a new paradigm shift, namely from electronic publishing to digital publishing.

Digital publishing is a fully digital process, from end to end: cameras, scanners, processing, storage, retrieval, syndication, distribution, and rendering. Many underlying electronic imaging technologies remain the same. However, the new fully digital process changes the emphasis of which goals are more important, i.e., it requires us to reconsider the priorities in our research programs and objectives. We briefly review the impact on some application areas.

Cameras

As it becomes digital, the technology for amateur cameras—USB peripherals—diverges quite substantially from the technology for professional cameras—workhorses. Professional digital cameras are now generally accepted as the most appropriate tool both in the studio—e.g., for catalog work—and in the field—e.g., sports and general reportage. Today's professional digital cameras fulfill the needs of their users and the main challenge for electronic imaging is to reduce the device cost by an order of magnitude to bring it more in line with the cost of the old AgX-based technology.

For the amateur market, we must revise our way of thinking. With the AgX technology, an amateur application is a scaled-down and simplified version of the professional application that can achieve more or less the same image quality. Over the last decade the photo amateur has been replaced by the photo consumer, and any digital photography application for the consumer must compete with disposable cameras. In the last couple of years we have seen the emergence of a new paradigm for consumer photography, namely the instantaneous and casual communication of candid images.

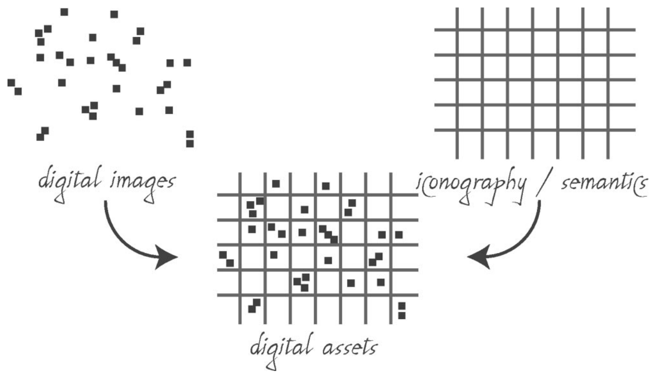
In this new paradigm for consumer photography, digital cameras are peripherals for hand-held computers and have to obey the rules for such peripherals, namely be very small and cost as much as a mouse. Regardless of these two constraints, the digital consumer camera has to work anywhere—like a disposable camera—but without a flash, because batteries are too bulky. The requirements from the different application areas place emphasis on several electronic imaging research topics, among them dynamic range and color constancy.

Processing

Contrary to the spartan requirements for digital cameras, image processing benefits from a bonanza in desktop computer power. With 500 MHz processors on 100 MHz system busses and 128M bytes of RAM, today's personal computers have bandwidth to spare after the user's primary requirements have been fulfilled. This leaves considerable performance available for improved color imaging.

New algorithms, more heavily based on non-linear methods and operating in more suitable representational spaces, can now be deployed even in such performance-critical system components as operating systems and device drivers. For example, if the optical properties for an inexpensive simple input device are well characterized, sophisticated algorithms can be used to restore images to unprecedented quality.

One of the main tools for research in color imaging science is colorimetry.



Balancing the imaging pipeline becomes easier because the color information is colorimetric instead of consisting of device counts. The increased attention to colorimetry brings new challenges to instrument accuracy—better than just noticeable differences is necessary to balance a pipeline. Furthermore, imaging scientists need a better understanding of color science so they can correctly interpret the colorimetric data.

This improved understanding of color will also allow imaging scientists to invent novel automatic image enhancement algorithms based on rendering intent instead of attempting exact color reproduction. This understanding will allow superior trade-off decisions that will make the systems more robust, and therefore simpler and easier to use. Copying a color image will no longer require a trained specialist; everybody will be able to reproduce their own images.

Intellectual property

On August 13, 1997, U.S. District Judge Sonia Sotomayor rendered a very important decision in Tasini *et al.* vs. New York Times *et al.* regarding copyrights (see http://www.nwu.org/nwu/tvt/tvtrule.htm). Her decision, based on section 201 (c) of the Copyright Act of 1976, which deals with the copyrights in collective works, reads that while the publisher of a collective work retains the copyrights for further publication in databases and CD-ROMs—she declared them revisions of the original work—authors retain the rights to individual contributions and may license them to World Wide Web publishers, without permission from or payment to the publisher. This is an opportunity for image syndication and will spur the need for electronic imaging technology.

With perfect timing, electronic imaging researchers are delivering the appropriate technology—watermarking. From the perspective of digital publishing, watermarking is a hot problem, as is evident from the intensive publication activity. Stock agencies are early adopters of electronic imaging, so the protection of the author's rights is a major priority. Watermarking facilitates the clearance of copyright royalties and allows the prosecution of thieves in case of unauthorized use of an image.

Scanning

A pressing problem that is attracting the attention of research in electronic imaging is the digitalization of the human cultural heritage. The documents created since the inception of digital publishing are only a minuscule fraction of the patrimony stored in archives. Originals are subject to various forms of decay and there is a certain urgency to digitize a huge number of documents. As much of the original information has to be preserved as possible, including pentimenti and documents under recoated media. Some of these documents are in a bad state of disrepair and can be restored only in a digital form, because the originals are too frail.

Storage and retrieval

Capturing an image is only part of the problem. It is further necessary to catalog the image, so it can be later retrieved by searching for criteria or by navigating the space of all images. Required algorithms encompass the fields of pattern matching, object recognition, character recognition—including old typefaces and calligraphy—and reverse graphic editors to convert bitmap representations into vector representation, which is essential for the large number of geographic maps stored in archives.

Specifying the iconography, i.e., the evolving semantic context of an image, is a very difficult task that requires extensive knowledge. To be useful for retrieving images from the World Wide Web, an iconography cannot be based on haphazardly assigned index words. Catalogers must be assisted by thesauri, taxonomies, and ontologies, which are essentially all the same artifact. These structures, also known as external intelligence, allow catalogers and image retrievers to navigate the set of images instead of performing flat keyword searches.

Catalogers are aided by image classifiers, which in turn can use the iconographic structures to improve their accuracy. Image classifiers are also becoming increasingly important for color gamut mapping. Depending on the output device, the rendering algorithm has to map the colors in the image to a gamut that has a considerably different gamut than the range of colors in the image. It is necessary to distort the color in the image but some fundamental memory colors such as complexion cannot be changed too much.

Output peripherals

Only a few years ago, printer MTF was so poor that images could be aggressively compressed using the example quantization tables from the JPEG standard specification. Today the quantization tables in lossy data compression algorithms must be designed very carefully to be perceptually lossless for the intended rendering devices and viewing conditions. This entails that the human visual system's MTF can no longer be used as a weighting function for quantization tables. Instead, the MTF of each stage in the imaging pipeline must be taken as a visibility threshold that must be matched to the MTFs of all other stages.

The increased use of images in documents poses new problems also to the choice of data compression algorithm classes for images. While JPEG and wavelets work well on full color images communicated over the Internet, these algorithms fail on halftoned images. The last cable to the printer has become a severe performance bottleneck and we need lossless compression methods like JBIG, which do not destroy the structure of halftones.

When we design electronic imaging algorithms for digital publishing systems, we shall not forget that some of our technologies are taking a large human toll. As we noted earlier, our new technologies are the basis for tools allowing everyone to do their digital publications by themselves. The pre-press industry, which worldwide employs an amazing number of imaging experts working in small businesses, is on the verge of disappearance. While mechanical paste-up assembly and stripping have gone the way of the buggy whip trade, we should not waste the specific knowledge in the pre-press industry. These talents are very much needed in the new world of digital publishing, especially now that we have to reconsider our research priorities. For example, a trained eye can take us a long way in end-to-end MTF optimization and choosing the most appropriate compression algorithms.

The papers in this special section cover many of the topics mentioned in this introduction. A journal's purpose is to facilitate and stimulate contacts and exchanges between established researchers and those new to the field, either because they are at the dawn of their career, they are broadening their expertise, or they are shifting their focus as job descriptions evolve. Sharing their latest results and ideas are the experts in color imaging, the people that are working on the disruptive technologies enabling the paradigm shift from electronic to digital publishing.

Giordano Beretta received his doctorate in computer science from the Swiss Federal Institute of Technology, Zurich, in 1984, and joined Xerox PARC that year. For his pioneering work in color imaging he received the 1989 Xerox Corporate Research Group Achievement Award. In 1990 he moved on to Canon, where as a senior scientist he was involved mainly in strategic planning and intellectual property management, while exercising his technical skills as the Technical Advisor for Color. Since 1994 he has been with the Computer Peripherals Laboratory at Hewlett-Packard. A strong believer in the social role of synergies and emergent properties, he is a tireless promoter of young scientists and engineers, helping them in their first professional steps; he also teaches short courses and organizes conferences. His skills as a speculative designer have translated into a number of patents and articles. He is a member of ISCC, IS&T, SMS, and SPIE.

Reiner Eschbach received his MS and PhD in physics from the University of Essen, Germany, in 1983 and 1986, respectively. From 1986 to 1988 he was a visiting scholar at the University of California, San Diego. He joined Xerox in 1988 where he became a principal scientist at the Xerox Digital Imaging Technology Center in 1994. Dr. Eschbach holds more than 30 patents in the areas of image enhancement, halftoning, compression and color imaging. In 1994 he received the Xerox Eagle Award given to employees with the most patents issued for a given calendar year. Currently he is the project leader for the Image Science Group in the Color and Digital Imaging Systems Lab. His research interests include color image processing, digital halftoning and compression. He has published more than 20 papers in various peer reviewed journals and has given presentations at numerous conferences. He has also been actively involved in the planning and organization of several conferences in the US and abroad. He is the editor of the *Recent Progress Series* and he is serving on the Board of Directors of IS&T as Publications Vice President.